AD-A098 239 NATIONAL RESEARCH COUNCIL WASHINGTON DC COMMITTEE ON--ETC F/G 5/10
THE EFFECTS OF TIME-VARYING NOISE ON SPEECH INTELLIGIBILITY IND--ETC(U)
1981 N00014-80-C-0159
UNCLASSIFIED NL

END
DATE
FILMED
5 81
DTIC

NRC NAS NAE IOM

LEVEL II

6

Contract N00014-80-C-0159

6

15 N00014-80-C-0159

6 THE EFFECTS OF TIME-VARYING NOISE ON SPEECH INTELLIGIBILITY INDOORS

Report of Working Group 83

Committee on Hearing, Bioacoustics, and Biomechanics
Assembly of Behavioral and Social Sciences
National Research Council

12 23

National Academy Press
~~Washington,~~ D.C.
11 1981

410223

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1963, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This work relates to Department of the Navy Contract N00014-80-C-0159 issued by the Office of Naval Research under Contract Authority NR 201-124. However, the content does not necessarily reflect the position or the policy of the Department of the Navy or the Government, and no official endorsement should be inferred.

WORKING GROUP 83

GILBERT TOLHURST (Chairman), Department of Communication Disorders, University of Massachusetts

CHARLES BERLIN, Kresge Hearing Research Laboratory, Louisiana State University Medical School

ALVIN LIBERMAN, Haskins Laboratories, New Haven, Connecticut

CHARLES W. Nixon, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio

KARL PEARSONS, Bolt Beranek and Newman, Inc., Canoga Park, California

CARL WILLIAMS, Naval Aerospace Medical Research Laboratory, Pensacola, Florida

COMMITTEE ON HEARING, BIOACOUSTICS, AND BIOMECHANICS

PETER WESTERVELT (Chairman), Department of Physics, Brown University

SHEILA BLUMSTEIN, Department of Linguistics, Brown University

BARBARA BOHNE, Department of Otolaryngology, Washington University School of Medicine, St. Louis, Missouri

KENNETH ELDRED, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts

DONALD H. ELDREDGE, Central Institute for the Deaf, St. Louis, Missouri

JAMES FLANAGAN, Acoustics Research Department, Bell Telephone Laboratories

DENNIS McFADDEN, Department of Psychology, University of Texas

DONALD PARKER, Department of Psychology, Miami University, Oxford, Ohio

CARL SHERRICK, Department of Psychology, Princeton University

CHARLES S. WATSON, Boys Town Institute for Communicative Disorders in Children, Omaha, Nebraska

MILTON A. WHITCOMB, Study Director
ARLYSS K. WIGGINS, Administrative Secretary

CONTENTS

INTRODUCTION

The formation of Working Group 83 resulted from the observation by several members of the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) that a need exists for information concerning the effects of time-varying noise on an indoor instructional environment. The determination of the effects of time-varying noise in general, and aircraft noise in particular, on speech intelligibility and learning in a classroom environment was the initial charge of the Working Group. However, it became apparent during the first meeting of the Working Group that not only was there a meager data base relating noise and learning, but the learning problem itself entailed a very large number of variables. Additionally, it became apparent that there was no agreement regarding the measurement of general learning (or even specific sample topics) that is applicable across regions, educational levels, teaching methodologies, and motivational levels. Therefore, the Working Group decided to consider only the effects of time-varying noise upon speech intelligibility. As an operational definition, "time-varying noise" is noise that modulates or is superimposed on some level of relatively steady-state background noise.

In this report an attempt is made to summarize and describe the present state of knowledge of the effects upon speech intelligibility of (1) steady-state noise, using selected data that are pertinent and applicable, and (2) discrete noise events modulating a steady-state background noise level. In addition, the characteristics of time-varying aircraft and traffic noise are described and the reactions of both talkers and listeners to such noises are reviewed. However, the discussion and the bibliography concerning the effects of noise upon speech intelligibility are certainly not exhaustive with respect to the interference effects of noise on communication. Tentative, interim relationships between time-varying noise and speech intelligibility are suggested and recommendations for research are made that might provide data leading to accurate predictions of these effects of noise. Finally, a method is suggested for measuring the degree to which time-varying noise affects the intelligibility of speech in indoor, classroom-like environments.

REVIEW OF THE RESEARCH

Steady-State Noise Effects

It is known that sound-pressure level (SPL) measures of noise alone do not predict speech intelligibility in that noise (Miller, 1947), although there is a monotonic relationship between speech intelligibility and speech-to-noise ratio (S/N) for most noise spectra up to approximately 15-20 dB S/N (Hudgins, Hawkins, Karlin, and Stevens, 1947; Egan and Wiener, 1946). This relationship, which seems to hold for white noise and most environmental noises (Webster, 1965, 1969; Webster and Klumpp, 1963; Wilbanks, Webb, and Tolhurst, 1956), provides the basis for a measure called the Articulation Index (AI).

The speech interference effects of many steady noises can be predicted computationally by the AI methodology, which was orginally developed by French and Steinberg (1947) and refined by Beranek (1947). It is now calculated from the difference between the measured levels of speech and noise in 20 equal speech-interference frequency bandwidths, or in octave or one-third octave bands properly weighted to account for their contributions to speech intelligibility (ANSI S3.5, 1969). By considerable experimentation under steady-state noise conditions, relationships between AI and various measures of speech interference have been established and are quite stable (Hudgins, Hawkins, Karlin, and Stevens, 1947; French and Steinberg, 1947; Kryter, Licklider, Webster, and Hawley, 1963; Kryter and Whitman, 1965; Kryter, 1962a; Kryter, 1962b; ANSI S3.5-1969, 1969; Klumpp and Webster, 1963; Webster and Klumpp, 1963). Although AI is the primary method for predicting speech intelligibility, other techniques are employed for setting levels of background noise in which communication can take place. These include speech interference level (SIL), A-weighted sound level (SLA), and perceived noise level (PNL). Tests indicate that in conjunction with speech levels these measures can be employed to predict speech intelligibility almost equally well (Kryter and Williams, 1966; Webster, 1973, 1978, 1979; Webster and Cluff, 1974; ANSI S3.14-1977, 1977).

Although the direct effects of steady-state noise on the intelligibility of speech are well known, we do not know how intelligible speech has to be for various classroom activities. Some researchers have investigated "ratings" of noise in environmental areas where speech communication is important. Nober (1973) found that auditory discrimination scores were depressed significantly in her "noisy" classroom, 65 dB SLA. Nober and Seymour (1974) indicated that their recordings of "average" classroom noise levels of 62 dB SLA affected speech intelligibility significantly, especially when the S/N was 0 dB, as opposed to conditions in which there was either no noise or a 10 dB S/N. McCroskey and Devens (1977, 1978) reported that auditory discrimination (as well as visual discrimination and performance on visual-motor tasks) are adversely affected by background noises ranging from an SLA of 57-68 dB.

Time-Varying Noise Effects

The speech interference effects and annoyance ratings of time-varying noises have not been studied extensively. The types of noise used in the laboratory and field investigations reported below include railway, roadway, aircraft traffic, and white noise. Certain speech intelligibility indices relating time-varying noise measures to interference effects have been attempted.

One factor in considering the effects of time-varying noise in indoor (classroom) environments is that any noise, such as intruding traffic noise, will be superimposed on a nearly steady-state noise base that is generated by students. Any calculation method that takes into account an octave or a one-third octave analysis of the noise would predict that the noise producing the greatest interference to speech intelligibility for a given noise level would be "speech" noise, common to classrooms (Egan and Wiener, 1946; Hirsh, Davis, Silverman, Eldert, and Benson, 1952; Nabelek and Pickett, 1974).

Intelligibility and Performance

Different rates of interruption of repeated white noise bursts that were presented "on" one-half the time and "off" one-half the time at several signal-to-noise ratios were found to affect speech reception if the interruption rate was below one cycle/second. At noise interruption rates of above 200 cycles/second, the noise was effectively continuous (Miller and Licklider, 1950).

Bronzaft and McCarthy (1975) published their findings of a study relating elevated railway noise and scores on word knowledge and word comprehension tests. A school, the site of the study, had classrooms located as close as 200 feet from the railroad tracks ("near-side" rooms). The "opposite-side" rooms (away from the tracks) were quieter. The average noise level in the "near-side" classrooms when no trains were passing was 70 dB SLA. When the trains were passing, the noise level averaged 89 dB for each of the 30-second duration 80 per day train passes. The performance test scores of the children in the "near-side" classrooms were significantly lower than in the "opposite-side" classrooms in nine of the ten matched classes.

For highway traffic noise, Pearsons, Bennett, and Fidell (1977) demonstrated that the equivalent sound level (L_{eq}) measure exhibited a smaller range of levels for the same observed degree of annoyance or speech intelligibility than L_{10}, L_{50}, noise pollution level (NPL), or traffic noise index (TNI). The superiority of the L_{eq} measure was maintained for noise samples whose ($L_{10} - L_{50}$) differences were within the range of 0.4 to 7.8 dB. However, for a constant L_{eq}, an increase in the noise variation increases the comprehension of continuous speech material.

Kryter and Williams (1966)--using recorded aircraft run-up, take-off, and landing noises--experimentally assessed the predictive value of different physical measures in estimating the speech interference effects of aircraft noise. The most predictive measure was the one that exhibited the least range of intelligibility scores at any specified noise level, although there was a wide spread of intelligibility test scores at comparable noise conditions for all measures. The rank order of predictive value of the various physical measures, from least to most predictive, was as follows: overall SPL, SLA, noise criterion curves (NC), speech interference level (SIL) (600-4800 Hz), PNL, and AI (the latter with either one-third or octave band calculation). A later study (Williams, Stevens, and Klatt, 1969) found a deterioration in speech message comprehension when aircraft flyover noise exceeded 88 dB PNL, 68 SIL, or 76 dB SLA, for an overall speech level of 72 dB.

A study employing time-varying aircraft noise (Williams, Pearsons, and Hecker, 1971) determined that AI, SIL, PNL and SLA were nearly equally effective in predicting word intelligibility. However, they found that the relationship between word intelligibility and AI is different for time-varying noise than for steady-state noise. For a given AI, time-varying noise provided less disruption (less speech masking) than steady-state noise, but there was disruption of contextual speech when the flyover levels exceeded those measured by Williams, Stevens, and Klatt (1969). Williams, Pearsons, and Hecker (1971) measured the temporal noise level relationships of take-off, landing, and flyover aircraft noise. The average duration of the noise observed--measured 20 dB down from the RMS (root-mean-square) peak level--was 35 seconds, and when measured 10 dB down from the peak, the durations averaged 10-18 seconds. If one accepts the duration of a syllable to be approximately 200 milliseconds, these figures allow the speculation that some 50-90 syllables could be masked during even a 10-18 second flyover duration unless there was a compensation in S/N provided by the increase of a talker's vocal effort in the presence of a masking noise.

Two studies provide data regarding expected noise levels in classrooms during aircraft flyovers. In the first study (Cohen, Evans, Krantz, and Stokols, 1979), four elementary schools in the Los Angeles area were surveyed. The number of overflights per day averaged 300 with mean peak levels ranging from 56 to 74 dB SLA and the highest levels ranging between 68 and 95 dB. There were no differences in performance scores on certain cognitive tasks between matched populations from "noisy" and from "quiet" home environments, but pupils from "noisy" environments gave up on tasks more often than pupils from "quiet" environments.

The second study was conducted in the vicinity of the Hong Kong airport where the school buildings had open windows and doors. Ko (1969) reports an average of 170 overflights per day with the mean peak aircraft noise levels ranging from 65 to 106 dB SLA (with a standard deviation of 7.2). Five schools had mean peak levels above 100 dB, 16 schools above 95 dB, and 55 schools above 90 dB. Ko found a linear relationship between noise and number index (NNI) values and annoyance ratings as well as between NNI and ratings of disruption of verbal communication. In 49 of 70 schools, the teacher annoyance ratings were high. The noises were exceedingly annoying for the total teacher population when the NNI value exceeded 70. For this NNI value the strategy used by nearly all the teachers was to pause. No SPL measures were made of the vocal output of the teachers who "shouted." In a previous study, from which Ko took his methodology, Crook and Langdon (1974) obtained results that were highly similar but of lesser magnitudes than those found by Ko. Those results were to be expected since the noise level in the British classrooms where Crook and Langdon did their research was lower than in the Hong Kong classrooms.

Pearsons, Bennett, and Fidell (1977) measured speech levels in different time-varying noise environments. They found a correlation of -0.82 between AI and background noise levels. This means that intelligibility of conversations was found to be inversely related to background noise levels. From these data and the known relationships between AI and sentence intelligibility, an L_{eq} of 65 dB would yield a sentence intelligibility score of 97 percent. Sentence intelligibility for an L_{eq} of 80 dB would drop to 81 percent. Ongoing communication could be assumed to be relatively unimpeded until the L_{eq} of intrusive noise exceeds 70 dB.

Noise Assessment and Effects

From human judgment ratings conducted in an anechoic chamber, Pearsons, Bennett, and Fidell (1977) report that traffic noise of 47 dB L_{eq} was "not at all annoying" when speech was of a "low" or "moderate" comprehension level and that 55 dB L_{eq} yielded "slightly annoying" ratings. Also, for low levels of traffic noise (less than 65 dB SLA), without truck noise, the annoyance ratings were related to speech interference. That is, regardless of the level of the traffic noise, people were more annoyed at lower comprehension levels than at higher ones. For traffic noise above 65 dB SLA annoyance ratings were related mainly to the sound level of the noise. Stated another way, at levels below 65 dB annoyance depends on speech intelligibility, and at levels above 65 dB annoyance depends on the level of the noise.

Williams, Stevens, and Klatt (1969) had listeners rate the acceptability of aircraft noise in the presence of speech. An increase or decrease in the level at which the speech was presented resulted in an increase or decrease in acceptability. The investigators stated that listeners appear to judge aircraft noise acceptability on the basis of the influence of the noise on spoken language communication, or, said another way, communication by speech apparently sets a limit upon the amount of noise considered acceptable. Measures of PNL, SIL, SLA, and AI were found to predict the acceptability of aircraft noise about equally well. Similar results were noted for steady-state aircraft noise rated from the interior of airplanes (Pearsons, Bennett, and Fidell, 1977).

Speech Levels

An important parameter in determining the intelligibility of speech is the vocal effort used to produce a certain speech level at the talker's ear. Although speech levels have been measured under laboratory conditions (French and Steinberg, 1947), only recently have speech production levels been measured in different noise environments.

Pearsons, Bennett, and Fidell (1977) determined speech levels of teachers in lecturing situations and also of individuals talking in homes, stores, hospitals, and transportation vehicles. The average speech level for non-teacher talkers was a constant 55 dB SLA when the background noise did not exceed an L_{eq} of 45 dB; for increases in the noise above this level, talkers tended to increase their voice level 0.6 dB for a 1.0 dB increase in the noise level. Depending on the communicating task, other investigators have found vocal level increases of from 0.3 dB (Beranek, 1947; Black, 1950; Korn, 1954; Botsford, 1969) to 0.5 dB (Webster and Klumpp, 1962) for a noise increase of 1.0 dB. (See Pickett (1958) and Lane, Tranel, and Sisson (1970) for a review of this subject.) The vocal levels of the teachers while lecturing (Pearsons, Bennett, and Fidell, 1977), when normalized to a one-meter distance, averaged 71 dB SLA, some 16 dB higher than the average of the non-teacher talkers. The teachers' vocal level compensations for increases in time-varying background noise level averaged 1 dB for each 1 dB noise level increase until their normalized speech level reached 78 dB SLA, a level judged to be between a "loud voice" and a "shout." This vocal level compensation seems to be in agreement with results of McCroskey and Devens (1977, 1978) who noted that teachers tended to maintain a constant 6 dB speech-to-noise ratio even when the people-generated noise in the classrooms changed from 57 to 68 dB SLA.

Summary

In summary, although not nearly as much is known about the effects of time-varying noise on speech intelligibility as is known about the effects of steady-state noise on speech intelligibility, there remains the problem of how intelligible speech must be in order to achieve acceptable communication in various time-varying noise situations. Further, it is important to understand how much people are willing to raise their voices to compensate for brief increases in background noise level.

It appears that, all things considered, several conclusions can be drawn from the limited evidence now available. First, AI is probably the best measure for the prediction of speech intelligibility. Second, at an L_{eq} for which a steady noise will interfere with speech intelligibility, there will be less interference by noise that varies in time. Third, people tend to talk with a higher SPL when lecturing than when conversing. They raise their voices during lecturing 1 dB for each 1 dB of increase in background noise until their voice level reaches about 78 dB if measured at one meter, a loud vocal level. During conversations, however, individuals tend to increase their vocal effort only from 0.3 to 0.6 dB for every 1.0 dB increase in background level depending upon the nature (importance) of their communications task. Fourth, annoyance ratings of road traffic noises below 60 dB SLA are related to speech interference; above that level, annoyance is a function of the intensity of the noise.

The preceding findings were obtained from a limited number of laboratory and field studies and under a variety of circumstances. At the present time, the Working Group cannot recommend upper limits for noise levels that will not interfere with the reception of speech, specific functions that relate loss of intelligibility of speech to levels of time-varying noises, or methods for the calculation of any of these relations. It does seem likely that the amount of speech interference resulting from time-varying noise may eventually be predicted by some existing computational methods. Logically it seems to us that the noise should be specified in terms of a L_{eq} peak or quasipeak level and that the speech interference index should be some running estimate that combines background noise and time-varying noise episodes in which the noise level is within 10 dB of the peak level. (For most aircraft flyovers the time period for this "10 dB below peak level range" is approximately 10 to 18 seconds.)

For school situations, it is suggested that specifying certain AI limitations may be the best approach that can be taken at this time. In classrooms where instruction is taking place, the levels of noise and speech should be such that the AI is never less than 0.4 for any location in the room. The 0.4 AI limitation would mean that for adults, word intelligibility would never be less than 60 percent or sentence intelligibility less than 92 percent. For children, however, reductions of these intelligibility indices by 10 percent may not be uncommon. Ideally, the AI should be 0.7 or greater at all times for classroom situations, especially under time-varying noise conditions.

SUGGESTIONS FOR RESEARCH

In view of the limited data available, a considerable portion of the time of the Working Group was spent considering suggestions for additional research. The following partial list of topics is abstracted from those sessions and does not imply inclusiveness or order of priority; it is limited to investigations of time-varying noise under field and laboratory conditions.

Field Studies

1. Rather large-scale samplings of the internal and external noise environments of classrooms and public buildings as well as of the speech levels in them are needed to serve as a base for the accurate prediction of the effects of such noise environments on instructional communication and subjective annoyance. These samples should be obtained from "noisy" and "quiet" environments in many and diverse geographical areas.
2. Studies should be undertaken to assess annoyance as a function of various amounts of noise intrusion into classrooms and public buildings.
3. There is a need to investigate a variety of behavioral measures (pupil attitudes, absenteeism, motivational patterns, etc.) that might, after validation, be used as indicators of "noisy-unacceptable" or "quiet-acceptable" instructional situations.
4. A determination should be made as to whether instructors resort to other pedagogical strategies (use of visual gestures or more elaborate pantomine, as well as use of other sense modalities) as noises rise to, or above, levels that would necessitate sustained high vocal levels.
5. Eventually the overall effects of time-varying noise on learning should be studied to determine the magnitude of the problem in the classroom environment.

Laboratory Studies

1. Laboratory studies should be initiated in which representative schoolroom background noise levels are modulated by different rates and levels of aircraft flyover noises and the speech intelligibility interference is assessed by word, sentence, and paragraph speech tests. These data would allow extension of methods to determine more efficient calculation techniques.

2. Most intelligibility tests involve "normal" talkers and listeners. However, to determine a more complete range of intelligibility criterion scores in time-varying noise, special groups should be used in testing. Such groups should include the hard of hearing and those with language or speech difficulties.

3. Data are needed concerning the extent to which both teachers and pupils will, and can, adapt their vocal outputs to compensate for different levels of time-varying noises. The data should include a determination of the noise levels(s) above which instructors will <u>not</u> further raise their voices to compensate, i.e., will quit talking. The length of time instructors will maintain their maximal sustained vocal effort should also be measured.

4. In this report, the AI calculation is tentatively suggested as an index of speech interference caused by time-varying noise. Since AI is based on experiments using steady-state noise, a correction factor for AI should be experimentally determined for time-varying environmental noises.

GLOSSARY

Term	Abbreviation or Symbol	Definition
Sound pressure level	SPL	A logarithmic measure (in decibels (dB)) of the ratio of a sound pressure (P) relative to an explicitly stated reference sound pressure (P_{ref}). A widely used P_{ref}, approximately equal to the human hearing threshold, is 20 μ Pascals (0.00002 newtons/meter) and is related to P according to the following formula: $SPL_{(in\ dB)} = 20 \text{ Log } \frac{P}{P_{ref}}$
A-weighted sound level	SLA	Sound pressure level modified to de-emphasize the low frequency portions of sounds. It is one of several such weightings (A, B, C, D) found on a sound level meter which attempts to approximate the response of the human ear to sound.
Equivalent sound level	L_{eq}	The level of the A-weighted sound pressure when squared and averaged over some specific period of time. It is also referred to as average sound level and is typically used as a measure of time-varying noise.
Statistical sound level	L_{10}	The noise level (usually A-weighted) which is exceeded 10 percent of the time.
	L_{50}	The noise level (usually A-weighted) which is exceeded 50 percent of the time.

Term	Abbreviation or Symbol	Definition
Noise criterion curves	NC	Sets of octave band levels established to provide a single number rating for octave band noise spectra.
Signal-to-noise-ratio	S/N	The ratio of the signal energy to the background noise energy. It is usually reported in the number of decibels by which the signal exceeds the noise.
Articulation Index	AI	A calculated measure which weights the difference between the speech signal and the background masking noise in an effort to estimate the proportion of normal speech signal that is available to a listener for communication purposes. The results for AI range from 0 to 1.0 where 1.0 is equated with 100 percent intelligibility.
Speech Interference level	SIL	The arithmetic average of the sound pressure levels in the four octave bands centered at the frequencies of 500, 1000, 2000 and 4000 Hz.
Perceived noise level	PNL	A noise rating calculated from octave or one-third octave sound pressure levels.
Noise and number index	NNI	The average maximum perceived noise level (PNL) of noise events occurring within a time period plus a correction related to the number of events.
Noise pollution level	NPL	A noise rating based on equivalent sound level plus a measure of the variation of the noise level over a specified period of time.
Traffic noise index	TNI	A noise rating which accounts for the amount of variability of level in A-weighted sound measurements.

REFERENCES

American National Standards Institute (ANSI) (1969) Methods for the calculation of the articulation index. ANSI S3.5-1969.

American National Standards Institute (ANSI) (1977) Standard for rating noise with respect to speech intelligibility. ANSI S3.14-1977, ASA 21.

Beranek, L.L. (1947) Design of speech communication systems. Proc. Inst. Radio Eng. 35:880-890.

Black, J.W. (1950) The effect of room characteristics upon vocal intensity and rate. J. Acoust. Soc. Amer. 22:174-176.

Botsford, J.H. (1969) Using sound levels to gauge human response to noise. Sound and Vibration 3:16-28.

Bronzaft, A.L. and D.P. McCarthy (1975) The effect of elevated train noise on reading ability. Environ. and Behavior 7:517-527.

Cohen, S., G.W. Evans, D.S. Krantz, and D. Stokols (1979) Physiological, motivational and cognitive effects of aircraft noise on children: moving from the laboratory to the field. Unpublished paper.

Crook, M.A. and F.J. Langdon (1974) The effects of aircraft noise in schools around London airport. Journal of Sound and Vibration 34:221-232.

Egan, J.P. and F.M. Wiener (1946) On the intelligibility of bands of speech in noise. J. Acoust. Soc. Amer. 18:435-441.

French, N.R. and J.C. Steinberg (1947) Factors governing the intelligibility of speech. J. Acoust. Soc. Amer. 40:90-119.

Hirsh, I.J., H. Davis, R.S. Silverman, E. Eldert, and R. Benson (1952) Development of materials for speech audiometry. J. Speech Hear. Res. 17:231-237.

Hudgins, C.V., J.E. Hawkins, J.E. Karlin, and S.S. Stevens (1947) The development of recorded auditory tests for measuring hearing loss for speech. Laryngoscope 57:57-89.

Klumpp, R.G. and Webster, J.C. (1963) Physical measurements of equally speech-interfering navy noises. J. Acoust. Soc. Amer. 35:1328-1338.

Ko, N.W.M. (1979) Responses of teachers to aircraft noise. Journal of Sound and Vibration 62:227-292.

Korn, T.S. (1954) Effect of psychological feedback on conversational noise reduction in rooms. J. Acoust. Soc. Amer. 26:793-794.

Kryter, K.D. (1962a) Methods for calculation and use of the articulation index. J. Acoust. Soc. Amer. 34:1689-1697.

Kryter, K.D. (1962b) Validation of the articulation index. J. Acoust. Soc. Amer. 34:1698-1702.

Kryter, K.D. and C.E. Williams (1966) Masking of speech by aircraft noise. J. Acoust. Soc. Amer. 39:138-150.

Kryter, K.D., J.C.R. Licklider, J.C. Webster, and M. Hawley (1963) Speech communication. In C.T. Morgan, J.S. Cook, A. Chapanis, and M.W. Lund (eds.). In Human Engineering Guide to Equipment Design. McGraw-Hill: New York.

Kryter, K.D. and E.C. Whitman (1965) Some comparisons between rhyme and PB-word intelligibility tests. J. Acoust. Soc. Amer. 37:1146(L).

Lane, H., B. Tranel, and C. Sisson (1970) Regulation of voice communication by sensory dynamics. J. Acoust. Soc. Amer. 47:618-624.

McCrosky, R.L. and J.S. Devens (1977) Effects of noise upon student performance in public school classrooms. NOISEXPO Proceedings, Chicago, Illinois, 125-129.

McCrosky, R.L. and J.S. Devens (1978) Acoustic barriers: A seminar on public law 94-142. NOISEXPO Proceedings, Chicago, Illinois 92-94.

Miller, G.A. (1947) The masking of speech. Psychol. Bull. 44:105-129.

Miller, G.A. and J.C.R. Licklider (1950) The intelligibility of interrupted speech. J. Acoust. Soc. Amer. 22:167-173.

Nabelek, A.K. and J.M. Pickett (1974) Reception of consonants in a classroom as affected by monaural and binaural listening, noise, reverberation and hearing aids. J. Acoust. Soc. Amer. 56:628-639.

Nober, L.W. (1973) Auditory discrimination and classroom noise. The Reading Teacher 27:288-291.

Nober, E.H. and H.N. Seymour (1974) Speech recognition scores of white and black student-teacher listeners for black and white first grade speakers. Final Technical Report, Washington, D.C. HEW-NIE, February.

Pearsons, K.S., R.L. Bennett, and S. Fidell (1977) Speech levels in various noise environments. Washington, D.C., EPA-600/1-77-025, May.

Pearsons, K.S. (1978) The effect of time-varying traffic noise on speech communication and annoyance. Noise Control Eng. 10:108-118.

Pickett, J.M. (1958) Limits of direct speech communication in noise. J. Acoust. Soc. Amer. 30:278-281.

Webster, J.C. (1965) Speech communication as limited by ambient noise. J. Acoust. Soc. Amer. 37:692-699.

Webster, J.C. (1969) Effects of noise on speech intelligibility. In Noise as a Public Health Hazard. American Speech and Hearing Association (ASHA), Report 4, Washington, D.C.

Webster, J.C. (1973) The effects of noise on hearing speech. Proceedings of the Congress of Noise as a Public Health Problem, Dubrovnik, EPA Report 550/9-73-008. Government Printing Office 25-41.

Webster, J.C. (1978) Speech interference aspects of noise. In Noise and Audiology, D. Lipscomb (ed.), Chapter 7, University Park Press: Baltimore, Maryland.

Webster, J.C. (1979) Effects of noise on speech. In Handbook of Noise Control, Cyril Harris (ed.), Chapter 14, McGraw-Hill: New York.

Webster, J.C. and G.L. Cluff (1974) Speech interference by noise. Proceedings of the 1974 International Conference on Noise Control Engineering. Washington, D.C. 553-556.

Webster, J.C. and R.G. Klumpp (1962) Effects of ambient noise and nearby talkers on a face-to-face communication task. J. Acoust. Soc. Amer. 34:936-941.

Webster, J.C. and R.G. Klumpp (1963) Articulation index and average curve-fitting methods of predicting speech interference. J. Acoust. Soc. Amer. 35:1339-1344.

Wilbanks, W.A., W.B. Webb, and G.C. Tolhurst (1956) A study of intellectual activity in a noise environment. U.S. Naval School of Aerospace Medicine, Project No. NM 001 104 100, Report No. 1, Pensacola, Florida.

Williams, C.E., K.N. Stevens, and M. Klatt (1969) Judgements of the acceptability of aircraft noise in the presence of speech. Journal of Sound and Vibration 9:263-275.

Williams, C.E., K.S. Pearsons, and M.H. Hecker (1971) Speech intelligibility in the presence of time-varying aircraft noise. J. Acoust. Soc. Amer. 50:426-434.

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) National Research Council Committee on Hearing, Bioacoustics, and Biomechanics	2a REPORT SECURITY CLASSIFICATION None 2b GROUP None

3 REPORT TITLE

THE EFFECTS OF TIME-VARYING NOISE ON SPEECH INTELLIGIBILITY INDOORS

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)

Gilbert Tolhurst

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
March 1981	22	42

8a CONTRACT OR GRANT NO N00014-80-C-0159 b PROJECT NO c d	9a ORIGINATOR'S REPORT NUMBER(S) 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10 AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY

13 ABSTRACT

This report summarizes the effects upon speech intelligibility of both steady-state time-varying noise, particularly time-varying aircraft and traffic noises. Though no present measure adequately predicts this effect, the articulation index (AI) is recommended as the best available. In the classroom an AI of 0.4 is considered a minimum requirement for instruction and ideally, an AI of 0.7 or greater is recommended, especially under time-varying noise conditions.

DD FORM 1 JAN 64 1473

Security Classification

Security Classification

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
steady-state noise						
time-varying noise						
speech intelligibility						
masking						
teachers						
classroom						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

Security Classification

DA
FIL

5 -